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Collaborative Research: Linking Researchers and Graduate Students through COSEE Tools & Services

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Collaborative Research: Linking Researchers and Graduate Students through COSEE Tools & Services

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University of California-San Diego Scripps Inst of Oceanography

Rutgers University

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Waterville Senior High School (Maine)

Activities and Findings

Research and Education Activities:

Over the duration of the project, facilitators at the Centers for Ocean Sciences Education Excellence (COSEE) California, NOW and West received online training on use of COSEE-Ocean Systems? tools and techniques for conducting the Faculty-Graduate Student Collaborative workshop model. Frequent telecons and WebEx ?desktop sharing? sessions included representatives from all participating Centers. These meetings were used to collaboratively design survey instruments and analyze resulting data to improve the workshops (formative) and discover how participants had used what they learned in their own efforts (summative). Each of these team meetings was well documented (i.e., minutes were taken) and workshop documents (e.g., agendas, handouts, presentation materials) were shared. All minutes and workshop documents were placed into a password-protected online document repository (i.e., the COSEE File Manager).

In Winter 2010, a pilot workshop was held at the UMaine Darling Marine Center that challenged faculty, graduate students, and postdoctoral researchers to open new lines of communication at the academic level. Working in small groups, 17 graduate students/post-docs teamed with 5 faculty members from the University of Maine School of Marine Sciences (Peter Jumars, Larry Mayer, Andrew Pershing) and Bigelow Laboratory for Ocean Sciences (David Fields, Ben Twining). For this pilot and all subsequent workshops, teams were matched based on a quantitative analysis of the graduate students? pre-workshop feedback on their ?comfort with? and the ?relevance of? Ocean or Climate Literacy statements that reflected each faculty member?s area of research. These teams were asked to construct digital concept maps focused on ocean sciences research topics using software developed by COSEE-OS. They were collectively asked to target their maps for an audience of non-science undergraduates. The graduate students/post-docs were tasked with providing to the faculty a ?bridging perspective? to the undergraduate population, while the faculty in turn had a chance to explain and clarify their deep knowledge of complex science topics on a peer-to-peer level with the graduate students/post-docs. On the final day of the workshop, the graduate students/post-docs showcased their ?consensus? concept maps to Waterville Senior High School students, who critiqued their presentations and provided feedback.

In April 2011, twenty graduate students from USC, University of California Los Angeles (UCLA), and California State Universities at Fullerton, Los Angeles, and Long Beach participated in the COSEE-West workshop. Five faculty members from USC (Jed Fuhrman, Sergio Sanudo-Wilhelmy) UCLA (Peggy Fong, Aradhna Tripati) and Cal State Long Beach (Chris Lowe) also participated. Like the pilot workshop, representatives from each of the participating COSEE Centers co-facilitated the event. Faculty and graduate students developed concept map‐based presentations for high school students. On the final workshop day, the graduate students made presentations to an audience of high school

sophomores from Tesseract High School (Phoenix, AZ).

In mid‐May 2011, COSEE‐OS staff joined the COSEE Networked Ocean World team for a two‐ day workshop that brought together five scientists (Debashish Bhattacharya, Lee Kerkhof, James Miller, Oscar Schofield, and Elisabeth Sikes) and 20 graduate students from Rutgers University. The teams developed presentations tailored to audiences representing different segments of the general public and feedback and discussion was led by professional staff from Discover Magazine, the American Museum of Natural History, Liberty Science Center, and an independent producer of ocean science education documentaries. Each of those panelists reacted to the presentations and discussed them in the context of their own organizations? education and communication efforts.

The last of four workshops was held at Scripps Institution of Oceanography (SIO) in October 2011. The first half-day of the workshop included a concept-mapping training session for five SIO faculty members (Lihini Aluwihare, Kathy Barbeau, Dimitri Deheyn, Neal Driscoll and Brad Erisman). The second day was dedicated to teaming each faculty member with a small (3-4) group of SIO graduate students. Each group made an interactive concept map that they felt was suitable for an undergraduate audience. On the last half-day of the workshop, the graduate students presented their maps to undergraduates who assessed each presentation using the same factors as the previous three workshops (i.e., ?Big Picture,? use of ?Jargon,? the clarity of their ?Concept Map,? and ?Take Home Message?).

A summative evaluation survey was administered in January 2012 to graduate student participants from all four workshops. These data were included in a manuscript that was submitted (in August 2012) for publication in ?Oceanography? magazine. (Manuscript is attached under 'Findings.')

Findings: (See PDF version submitted by PI at the end of the report)

Training and Development:

The COSEE-OS Staff trained its collaborators on running the workshop that is derived from an existing model that has been well tested. In addition, these individuals were trained in the use of COSEE-OS software (i.e., ?Concept-linked Integrated Media Builder? or CLIMB).

Outreach Activities:

The very nature of this project ? increasing the ability of faculty, post-docs, and graduate students in ocean sciences to better communicate science to non-scientists ? supports professional development in outreach skills. For example, the pilot workshop (February 2010) included 15 students and 4 educators from Waterville Senior High School (Maine) who gave feedback on the age-appropriateness of the graduate students/post-docs presentations. In addition, the workshop processes and products are accessible by the general public on the COSEE-OS website. During the COSEE-West workshop (April 2011), graduate students presented the consensus maps to 18 high school students and three teachers from Tessaract High School in Phoenix, Arizona who provided feedback on the presentations and maps.

Journal Publications

Books or Other One-time Publications

Web/Internet Site

URL(s):

http://cosee.umaine.edu/coseeos/workshops/fgsc.htm

Description:

The website includes the 40 interactive concept maps (with descriptions) created by the faculty and graduate students during the four funded workshops. This page also includes links to individual overview pages for each of the four workshops.

Other Specific Products

Contributions

Contributions within Discipline:

This project relies heavily on products and processes originally developed by the COSEE-OS program to enhance and support collaborations between scientists and educators. In terms of products, COSEE-OS software tools have over 2,800 self-registered users who have created over 6,800 unique concept maps. The 'Scientist-Educator Collaborative' workshop model, upon which the ?Faculty-Graduate Student Collaborative Workshops? are based, has been transferred to at least one COSEE Center (i.e., Pacific Partnerships).

Fifty-one graduate students took the follow-up survey administered in January 2012 (70% of the 73 who participated in workshops). All were satisfied with assistance received in workshop. 90% of the respondents (n=51) indicated that they would recommend the workshop to their peers or colleagues and the same percentage stated that they would like more pedagogical training in their graduate program. 52% of the graduate students indicated the concept-mapping tools had been useful to them since the workshop and the remainder indicated that they were ?not sure,? in some cases citing the short time elapsed since the event itself.

The most likely uses of concept mapping in graduate students? broader impacts or educational outreach endeavors were to ?better organize thoughts? (63%; n=48) and ?provide a bigger picture or context? (54%; n=48). Concept mapping helped them both organize and place their research in a larger context. In terms of applying content or skills learned to their scientific research, the most frequent use of concept mapping was to ?organize thinking about an existing research/dissertation topic? (56%; n=48), ?develop research/dissertation topic? (44%; n=48), and ?explain research to my colleagues and/or peers? (43%; n=48). Nearly all (92%; n=47) who responded this question indicated that they have already or are planning to add concept mapping to their tools for organizing their research.

The graduate students were also asked about impacts related to NSF-defined ?Broader Impacts? areas. Twenty-two (45%; n=49) reported that the FGSC workshop had been helpful to them in meeting NSF-defined ?Broader Impacts,? particularly in the categories of ?Benefits to Society (77%; n=22) and ?Advance Discovery? (82%; n=22), the latter defined as ?advancing discovery and understanding while promoting teaching, training and learning.?

Contributions to Other Disciplines:

In 2010, COSEE-OS presented a poster about its software and workshops at the Society for Information Technology & Teacher Education International Conference in San Diego, CA. The authors, Carla Companion and Annette deCharon, won an ?Outstanding Poster Award? for this contribution.

Contributions to Human Resource Development:

Contributions to Resources for Research and Education:

Based on the Faculty-Graduate Student Collaborative workshop initiative, COSEE-OS has been helping to link graduate students in the UMaine School of Marine Sciences (SMS) with

new opportunities to further their training in educational pedagogy and communication. In Fall 2010, two SMS graduate students gave presentations about their careers and taught concept mapping to five Earth Science classes at Bangor High School. In April 2011, three SMS graduate students led field activities in the Damariscotta River estuary and gave presentations for 10 Gardiner Area High School freshman girls during an overnight field trip to the Darling Marine Center. In July 2011, five graduate students co-facilitated a COSEE-OS ?Curriculum Development Workshop? with pre-college educators at Colby College (Waterville, ME). In January 2012, COSEE-OS held a one-day workshop (Orono, ME) to familiarize SMS graduate students with hands-on activities illustrating ocean concepts, provided them with tools and tips for teacher and student interactions and expectations, and helped them create concept maps based on their graduate research using the COSEE-OS Concept Map Builder.

In April 2012, COSEE-OS, in collaboration with the Northeastern University (NU) Marine Science Center (MSC), hosted a Faculty-Graduate Student Collaborative Workshop at the MSC in Nahant, MA. Working in small groups, three faculty (Professors Matt Bracken, Jon Grabowski and Rebeca Rosengaus) collaborated with nine NU marine science graduate students to learn new skills for communicating to general audiences the ?big picture? messages found in their diverse research topics.

Contributions Beyond Science and Engineering:

Conference Proceedings

Categories for which nothing is reported:

Any Journal

Any Book

Any Product

Contributions: To Any Human Resource Development

Contributions: To Any Beyond Science and Engineering

Any Conference

Concept Mapping Workshops:-Helping Graduate Students Better Communicate Their Science

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ABSTRACT

Concept mapping facilitates "deconstructing" complex science into discrete ideas and organizing them into graphical formats. Based on recommendations by ocean science faculty who worked with formal pre-college educators during concept-mapping workshops, four Centers for Ocean Sciences Education Excellence (COSEE) revised a successful model –Scientist-Educator Collaborative (SEC) workshops – to focus on professional development for graduate students. In the resulting Faculty-Graduate Student Collaborative (FGSC) workshop model, 20 scientists guided 73 graduate students to better communicate their science to non-scientists. The FGSC model also incorporated pedagogical activities to illustrate the learning process and complement the focus on science content. A new design element for the FGSC workshops was the inclusion of non-scientist third-party audiences who provided valuable critique to graduate students on concept map-based presentations. Discussing the needs of these audiences allowed participants to work together towards a common objective: effectively presenting ocean sciences concepts and research in a visual format to non-scientists. The graduate students were highly rated by all audiences on their abilities to communicate core concepts and place topics within a broader scientific framework. In a follow-up survey, graduate students acknowledged the potential of concept mapping to enhance their professional skills, and to organize their own research.

BACKGROUND

As an extension of its efforts to spark and nurture collaboration and communication among ocean researchers and educators, four Centers for Ocean Sciences Education Excellence (COSEE) designed,

implemented, and tested workshops for faculty- and graduate-level scientists called the Faculty-Graduate Student Collaborative (FGSC) model. The FGSC model is based on an initial series of successful workshops conducted by COSEE-Ocean Systems (OS) called the Scientist-Educator Collaborative (SEC) workshop model, with the goal of bringing faculty-level scientists, who served as science content experts, together with pre-college formal educators well versed in guiding their students in organizing knowledge. A pre-college formal educator, hereafter referred to in this article as "educator," is defined as a professional teacher who works in the classroom setting within a school system in grades K-12. A pedagogical technique commonly used by these educators, "concept mapping," was the primary process employed in these workshops to break down complex scientific content into interrelated graphical components.

Concept maps are tools for visualizing and organizing ideas and processes, and for displaying the relationships among concepts using connecting lines and descriptive phrases. A simple concept map provides a way to illustrate how such maps are constructed at the basic level (**Figure 1**). The process of concept mapping was pioneered in the 1960s by cognitive researcher Joseph Novak to visually display the dynamic knowledge structure of children as they were introduced to basic science concepts (Novak and Gowin, 1984; Roth and Roychoudhury, 1993; Novak and Cañas, 2008). Concept maps originate in the learning philosophy called "constructivism" that is based on the pedagogical research that students construct their own understanding by reflecting on their personal experience and by relating new knowledge to what they already know. One of its main principles is that to be effective, a teacher must help the student to discover and organize his or her own meaning (Ausubel, 1978). Thus concept mapping can be used with learners to ascertain how they understand a new topic and can also be a means for on-going assessment (Heinz-Fry and Novak, 1990; Wallace and Mintzes, 1990; Novak and Musonda, 1991; Markham and Mintzes, 1994; Ruiz-Primo and Shavelson, 1996; Rye and Rubba, 2002).

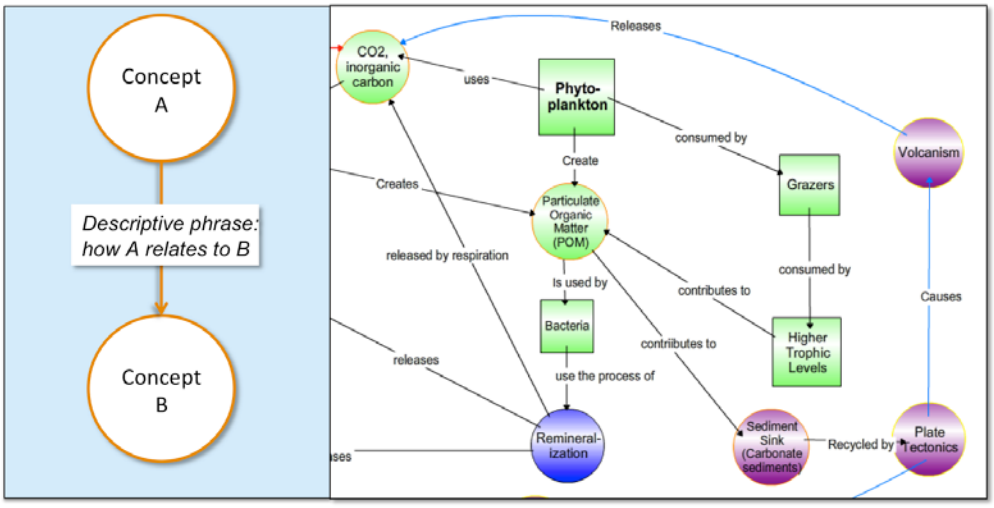

Figure 1: Left: Concepts, connections, and linking phrases that illustrate relationships between concepts are the fundamental parts of a concept map. Right: A portion of a concept map created at a FSGC workshop. All maps created during the workshops can be viewed at: *http://cosee.umaine.edu/coseeos/workshops/fgsc.htm.*

For content experts, such as the ocean scientists participating in these workshops, concept maps can illustrate not only their extensive knowledge, but also "how they organize, represent, and interpret information in their environment" (Bransford et al., 2000) – providing visualizations of the "the geography of an intellectual space" (National Research Council, 2006). **Table 1** summarizes educational research that compares how knowledge is gained, stored and retrieved by content experts versus novices. For educators, expert-created concept maps can serve as a valuable resource to both develop and assess students' evolution from surface attributes to meaningful patterns, from linear thinking to complex organization, and from rote memorization of facts to making relevant connections to "big ideas." **Figure 1** shows an example of a portion of an "expert concept map" created during a FGSC workshop. All 40 concept maps created during these ~~FGSC~~ workshops can be found at the following Web site: *http://cosee.umaine.edu/coseeos/workshops/fgsc.htm.*

Table 1. Abilities of Novices vs. Experts (based on Bransford et al., 2000)

Novices	Experts
Often focus on surface attributes	Notice features and meaningful patterns
Knowledge is remembered in lists of facts that make it less likely to see relationships	Knowledge organized in complex interrelated ways that affects how they remember, reason and solve problems
Approach problems by memorizing and searching for correct formulas	Knowledge organized around "big ideas" that guide thinking
Less likely to understand the conditions under which knowledge should be applied	Flexibly and selectively retrieve important and relevant aspects of their knowledge

While it has been shown that concept maps are an effective method to teach undergraduate students complex science content (Arnaudin et al., 1984; Ault, 1985; Cilburn, 1990; Novak, 1990; Briscoe and LeMaster, 1991; Mahler et al., 1991; Markow and Lonning, 1998; McClure et al., 1998; Rebich and Gautier, 2005), this article describes the development, implementation, and testing of a novel workshop model utilizing concept mapping to help graduate students communicate their science better – not only to their own communities but to non-scientist audiences in particular.

Evolution in Workshop Design

While this paper primarily focuses on the FGSC workshop results, the authors provide details of the "evolution" of the workshops from SEC to FGSC, including evaluation and comparison of data from both models, in order to better understand the rationale for the SEC workshop design.

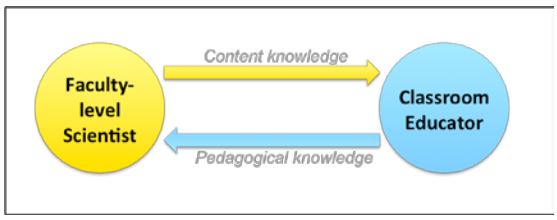

Figure 2. The Original Scientist-Educator Collaborative (SEC) workshop model, illustrating peer-to-peer collaboration between faculty-level scientists and pre-college formal educators.

Through evaluation of a series of five earlier workshops using the SEC workshop model, COSEE-OS found concept mapping to be an efficient method to gather useful information from scientists about their research, including how their knowledge is organized around "big ideas" (deCharon et al., 2009). Scientists worked towards a defined goal of creating a concept map with educators on a peer-to-peer basis, providing scientists with a pedagogical technique (concept mapping) that they perceived as being beneficial to their own work (**Figure 2**). Several faculty-level scientists, in post-workshop interviews, recommended that concept mapping be taught to graduate students in science fields. Faculty members specifically mentioned that concept mapping could help to broaden graduate students' views of science beyond their specific area of research.

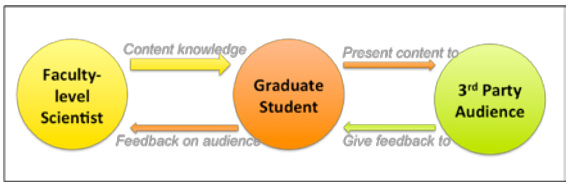

Figure 3. The new Faculty Graduate Student Collaborative (FGSC) model, in which faculty and graduate students engage collaboratively to create concept maps and present those maps to third-party audiences of non-scientists.

Given that the original SEC workshop model was based on bringing together professional scientists and educators as peers, simply substituting graduate students for faculty was not a practicable option, since the students shared a field, but not a level of expertise, with the scientists. Instead, investigators from four COSEE Centers proposed to pilot a "mentor-mentee" version of the SEC workshop (**Figure 3**). For the new FGSC model, they hypothesized that preparing a presentation for a third-party audience of non-scientists would partially offset the imbalance of expertise between faculty and graduate students, resulting in more peer-based interaction. Third-party audience types were chosen for either their relative closeness in age to the graduate students (e.g., undergraduate or high school students), or the fact that both the faculty and graduate students were unlikely to have worked extensively with them (e.g., non-scientists in informal education settings such as museums, aquariums, science centers, or in non-graded after-school programs). COSEE staff also recruited faculty and graduate students who were keenly interested in learning how to effectively communicate science to non-scientist audiences.

Table 2. FGSC Workshop Locations, Participants and Third-Party Audiences

COSEE Center	**Ocean Systems (OS)**	**West**	**Networked Ocean World (NOW)**	**California**
Month/Year	February 2010	April 2011	May 2011	October 2011
Participants' Home Institutions	University of Maine; Bigelow Laboratory for Ocean Sciences	USC; UCLA; Cal State Long Beach; Cal State Fullerton	Rutgers University	Scripps Institution of Oceanography
Number of Participants	17 grad students, 5 faculty members	20 grad students, 5 faculty members	20 grad students, 5 faculty members	16 grad students, 5 faculty members
"Third Party" Audience ***(Range: 5-40 people)***	High School Students	High School Students	Informal Education Audiences *(using experts in informal science education as proxies)*	Undergraduate Students *(both science and non-science majors)*

The third-party audiences were an integral part of the FGSC workshops, since in each case they represented both a motivation and a set of specific constraints for the graduate students' presentations. In addition, since the third-party audiences had little knowledge of the topics being presented, the graduate students and scientists could collaborate as peers in preparing their communications for them. In recruiting third-party groups, workshop organizers sought individuals who were interested in science and learning about science, but who were fairly unfamiliar with the topics that were being presented. The third-party audience types are included in **Table 2**.

Lessons Learned from Educator Workshops

The SEC workshop model (**Figure 2**), conducted at six venues in four states from November 2008 to June 2011, has demonstrated success in teaming research scientists and educators to collaboratively

create concept-map based content that is suitable for teaching pre-college students or informal education audiences. In post-workshop surveys, 89% of educators (n=106) replied "yes" when asked if concept mapping with scientists helped them "think through topics." Based on the success of using concept mapping with educators and scientists in SEC workshops to **think through topics,** this approach was used with graduate students and faculty in the FGSC workshops (**Figure 3**).

One of the keys to fostering collaboration – whether it is between scientists and educators or graduate students – is creating small teams whose team members each receive some benefit from the interaction. For the SEC workshops, COSEE-OS developed a quantitative method to match educators with scientists using statements from the *Ocean and Climate Literacy Essential Principles* (National Geographic Society et al., 2005; NOAA et al., 2008). These literacy documents were developed to capture "ideas scientists and educators agree everyone should understand." Published in 2005, Ocean Literacy (OL) and Climate Literacy (CL) were among the first frameworks to be widely adopted as guidance for designing science curriculum.

Box 1. Example Ocean & Climate Literacy Statements

"The ocean dominates the Earth's carbon cycle. Half the primary productivity on Earth takes place in the sunlit layers of the ocean and the ocean absorbs roughly half of all carbon dioxide added to the atmosphere."

"Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (symbiosis, predator-prey dynamics and energy transfer) that do not occur on land."

"Use of mathematical models is now an essential part of ocean sciences. Models help us understand the complexity of the ocean and of its interaction with Earth's climate. They process observations and help describe the interactions among systems."

"Environmental observations are the foundation for understanding the climate system. From the bottom of the ocean to the surface of the Sun, instruments on weather stations, buoys, satellites, and other platforms collect climate data."[22]

Box 2: Quantitative Matching Process

Ocean and Climate Literacy statements – selected based on the participating scientists' research areas – were used to gather data from educators in pre-workshop application surveys and match them in teams with scientists. Educators were asked to assess their comfort level with each literacy statement, along with its relevance to their work. Answer choices ranged from "Very" to "Not" and were assigned numerical values as follows:

Very comfortable	1	Very relevant	3
Comfortable	2	Relevant	2
Somewhat Comfortable	3	Somewhat relevant	1
Not comfortable	4	Not relevant	0

Each educator's comfort and relevance "score" was combined for each literacy statement. The higher the combined score, the more likely that educator would be matched with the individual scientist for whom that literacy statement was selected. The highest possible score, 7, represented educators who were "Not Comfortable" (4 points) with a particular statement but rated it as "Very Relevant" (3 points) to their classroom. In the SEC workshops, the higher combined scores were most often associated with statements pertaining to new technologies or use of mathematical models.

For the SEC workshops, COSEE staff identified a set of OL and CL statements that best aligned with the participating scientists' research areas, and these were included in educator application surveys (*examples of statements shown in **Box 1***). During the workshops, participating scientists worked with COSEE staff and educators to modify OL and CL statements to better reflect their own research; thus adherence to the original statements varied from scientist-to-scientist. In a pre-workshop application survey, educators rated their comfort with specific statements, along with the statements' relevance to their teaching situations; these data were used to match educators with scientists in teams using a quantitative process (*see **Box 2** for more details*). In post-workshop surveys, 90% of educators (n=67) answered "yes" when asked, "Was concept mapping helpful to you as a way to share ideas and 'build a bridge' for communication with the scientists?" Likewise, 91% of educators agreed that they "interacted

as peers/colleagues" during the workshop (n=66). Based on the success of matching educators with scientists to **promote collegial interactions during SEC model workshops**, the same methodology was used to match graduate students with faculty in the FGSC workshops.

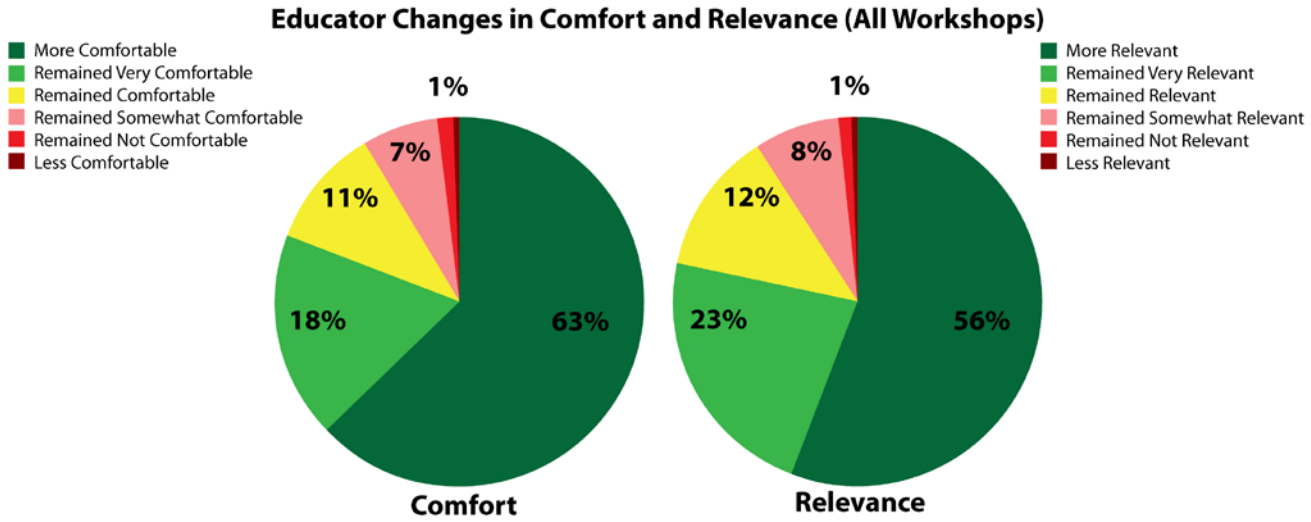

Figure 4. Post-workshop ratings by pre-college formal educators on the literacy statements covered in SEC workshops. The graphic depicts educators' (a) change in comfort level (left, n=686) and (b) perceived relevance of the literacy statements (right, n=681) to their work.

The OL and CL literacy frameworks served another important purpose: assessing self-reported *changes* after the workshop in educators' perceptions of their own *comfort* in teaching OL or CL content– along with their perception of these literacy statements' *relevance* to their teaching. Based on results from pre- and post-workshop surveys, **Figure 4(a)** shows change in educators' comfort with and perceived relevance to OL and CL statements. For SEC workshops, pre-workshop surveys were administered up to two weeks prior to each workshop, while post-workshop surveys were administered immediately following the workshops. Green areas on **Figure 4(a)** indicate that 81% of educators either became "more comfortable" or "remained very comfortable" with the content. Similarly, green areas on **Figure 4(b)** indicate that 79% either found the content became more relevant, or remained relevant after the workshop. Based on the success of the SEC workshops in **making positive changes with educators in terms of comfort and relevance**, the same methodology was used to assess the usefulness of OL or CL statements for graduate students in the FGSC workshops.

Graduate Student Workshop Participants & Objectives

The participants in the FGSC workshops were faculty-level ocean scientists and graduate students. **Table 2** shows the locations, participant numbers, and third-party audience types for each workshop. The pilot FGSC workshop was held in February of 2010 at the University of Maine's Darling Marine Center. Based on analysis of formative evaluation data from this pilot, the project team spent several months revising the workshop model and then tested its transferability to other settings with other facilitators. From April to October 2011, the workshop was run at three COSEE Centers around the country: COSEE West at the University of Southern California (USC), COSEE Networked Ocean World (NOW) at Rutgers University, and COSEE California at Scripps Institution of Oceanography. In coordination with facilitators at each COSEE hosting the workshop, COSEE-OS staff co-facilitated during the final three workshops to help provide continuity and assistance with the new workshop model.

Five main objectives and one longer-term objective for the FGSC workshop model are listed within brief contextual descriptions below. For each FGSC workshop, data were collected to evaluate all graduate student participants' overall satisfaction; these results were used to (1) *improve the FGSC workshop model* and *test the model's transferability* from venue-to-venue. Given that the FGSC workshops were derived from a well-tested model with demonstrated effectiveness with educators (SEC, **Figure 2**), graduate students were asked to evaluate workshop elements for many of the same objectives, including: (2) *Usefulness of concept mapping* to "deconstruct complex science"; (3) *Efficacy of strategies employed to foster collegial interactions* with faculty during workshops; and (4) *Change in comfort with or personal relevance of OL and CL statements*. In addition, during the workshop, faculty and graduate students both gave and received feedback on concept-map based presentations with the objective of: (5) understanding how concept maps can be used to give *effective presentations to a non-scientist audience.* Last, in a follow-on survey, graduate students provided feedback on the longer-term objectives of this project, including the *application of workshop content and/or skills* for educational outreach, teaching, and their scientific research.

METHODOLOGY

Consistent with the five objectives described above, FGSC workshops were designed with the following strategies in mind:

- Apply pedagogical techniques to ocean sciences content primarily through the use of concept mapping but also with targeted activities about how people learn, common misconceptions, and discussion of "homework" exercises that included asking non-scientists about basic ocean sciences content (see **Box 3**);
- Employ OL and CL frameworks to quantitatively match graduate students with faculty members and also measure graduate students' change in comfort with and perception of relevance with these fundamental statements; and
- Use a simple rubric to both give and receive feedback about concept-map presentations in these four categories: (i) big picture; (ii) jargon; (iii) organization of the concept map; and (iv) take-home message.

Each of the workshops was held over a three-day period, starting with faculty orientation during the afternoon before the graduate students arrived. Faculty members were given an overview of the graduate students' binned responses to the pre-workshop application survey including data on their academic training, fields of study, confidence in presenting/translating scientific information to general audiences, experience as educators, and their feedback on (i.e., comfort with, relevance of) OL and CL statements that best aligned with the faculty members' own research. Faculty used these literacy statements as references in formulating their own preliminary concept maps.

Concept maps and associated content produced as a result of these workshops are available at: http://cosee.umaine.edu/coseeos/workshops/fgsc.htm.

Typical format for the FGSC workshops:

Box 3: Pedagogical Activities Used During FGSC Workshops

How People Learn – Participants were guided through a series of activity stations, each employing a different part of the "learning cycle" to present the same science topic. Post-activity, they discussed how each method might affect students' individual learning styles *(Lawrence Hall of Science, 2008).*

Common Misconceptions – Participants considered strategies for dealing with students' misconceptions and their influential role in the learning cycle –in part by watching the video *A Private Universe (Schneps and Sadler, 1988),* and investigating temperature and salinity effects on ocean density during a hands-on activity.

"Homework" Exercise – Participants interviewed non-scientists, asking them two open-ended questions about basic ocean concepts. Group discussion of the responses reinforced that scientists need to first understand their audiences' knowledge base in order to effectively convey complex science content.

- *Afternoon of Day One* - Faculty scientists were trained on creating concept maps and shared their preliminary maps, designed for that workshop's third-party audience **(Table 2),** with peers and COSEE staff to receive constructive feedback;
- *Morning of Day Two* – Faculty scientists presented their preliminary concept maps to the graduate students who rated the presentations using a standard four-category rubric described previously;
- *Afternoon of Day Two* – Faculty scientists and graduate students were placed in small teams, typically one faculty member per three students (**Figure 5**). Together, each team: (i) learned about specific aspects of pedagogy through workshop activities; (ii) discussed and adjusted the faculty member's preliminary concept map for the third-party audience; and (iii) created digital interactive copies of their concept maps using COSEE-OS software, including attaching assets such as images and videos from the online database (http://cosee.umaine.edu/climb);
- *Morning of Day Three* – In teams, graduate students presented their modified interactive concept maps directly to third-party audiences or, in the case of the COSEE NOW workshop, to experts in informal science education who served as proxies for informal audiences **(Table 2).** Third-party audiences and other graduate students (the latter providing peer-level feedback to their fellow graduate students) used the same rubric to rate the teams' final presentations as were used on the morning of Day Two to rate faculty members' presentations.

Figure 5. Graduate students collaborate with faculty-level scientists to create concept maps at FGSC workshops held at Scripps Institution of Oceanography (top) and Rutgers University (bottom).

Evaluation:
Pre-workshop application surveys and post-workshop evaluation instruments administered online collected data from graduate students up to two weeks prior to and immediately after each workshop. Additionally, a "follow-up" online survey was sent simultaneously to all the graduate students in the workshop series four months after the final FGSC workshop (i.e., in January 2012).

FINDINGS

Collaboration and Sharing of Ideas

Data from the SEC workshop series – the model upon which the FGSC workshops were based – were shared in "Lessons Learned from Educator Workshops." **Table 3** compares educators' evaluation data collected via post-workshop evaluations with the same type of data from the graduate students who participated in the FGSC workshops. Like the SEC model, the FGSC model was uniformly well received regardless of the location. In general, graduate students' critiques of workshop organization and quality as recorded in post-workshop evaluations are similar to the responses given by educators. *This result supports the model's transferability from educators to graduate students as the primary participants (Objective 1).*

The only evaluation criterion in **Table 3** that shows a great disparity between educators and graduate students is in their responses to the question about the use of concept mapping to "share ideas and 'build

a bridge' with scientists/faculty." This difference is not unexpected because, unlike graduate students in science programs, educators do not usually have ready access to ocean sciences faculty members. In reviewing data from individual FGSC workshops, however, this question elicited a high range of responses: 94% of graduate students who participated in and completed an evaluation for the COSEE NOW workshop (n=18) answered "yes" compared with 50% of graduate students in the COSEE California workshop (n=16). Factors that may have contributed to this range of responses from workshop-to-workshop were not investigated, but may warrant further study. For example, unlike the COSEE California graduate participants who were all in the same department at Scripps Institution of Oceanography, the COSEE NOW workshop included students from several departments within Rutgers University.

Table 3. Direct Comparison of Post-Workshop Evaluation Data from Both Model Workshops.

	Pre-college Formal Educators (SEC Workshop)	N	Graduate Students (FGSC Workshop)	N
Concept mapping helped to "think through topics"	89%	106	85%	71
Share ideas and "build a bridge" with scientists / faculty	90%	67	68%	71
Interacted as peers / colleagues	91%	66	90%	71

*Answered "Yes" (all others chose "Sort of")

Table 3 findings support the usefulness of concept mapping in helping participants "think through topics" while preparing presentation materials for non-scientists. In addition, *deconstructing science into concepts and reorganizing the information to meet the needs of third-party audiences (Objective 2)* appears to have *fostered peer-based dialogue between faculty and graduate students (Objective 3).* These outcomes – along with the positive feedback from participating faculty members (see **Box 4** for examples) – support the overall efficacy of the workshops' design for both graduate students and faculty members.

Box 4: Select Quotes from Participating Faculty

"Hard part was doing the first draft of the concept map. (It was) relatively easy to work with the group to collaboratively improve the [map]."

"I found the workshop to be very beneficial for two reasons. First, the concept-mapping tool will help me to articulate the details of my research in a more coherent manner, particularly when asked to communicate it to different audiences. Second, I believe the concept-mapping tool can be an incredibly powerful way to organize lectures or to bring together concepts from several lectures into a larger model. "

"Using this mapping tool will help share my ideas and state a comprehensive image to my students, funding agency, and colleagues. (Concept mapping) is great in the sense that it can serve as a self-reflecting tool... if your map is not clear to others, that means your ideas are not clearly organized in your head!"

These encouraging results might also be interpreted as supporting the strategy of using graduate students' application survey data about OL and CL statements as a viable matching tool. During the workshops, however, many of the faculty had difficulty situating their own research within specific OL or CL statements, often citing the literacy statements' broad scope as challenging starting points for mapping out their own more narrowly-focused and detailed research topics. One of the lessons learned by FGSC workshop facilitators was that, although literacy frameworks were useful in designing the pre- and post-workshop data collection methodology, the generality of the OL and CL statements often made them difficult to align with scientific research. Thus future endeavors should include investigating other frameworks that suitably represent current scientific research while providing "layperson-appropriate" benchmarks that can be used to evaluate pre- and post-workshop changes.

Perception of Literacy Statements

Whereas SEC workshop educators showed significant gains in both their "comfort with" and their perceived "relevance of" OL and CL statements (**Figure 4**), *FGSC workshop graduate students had mixed results (Objective 4;* ***Figure 6****)*. Green areas in Figure 6a show that 68% of graduate students either became "more comfortable" or "remained very comfortable" with the OL and CL content. This outcome is fairly consistent with the educator data presented in **Figure 4a** (i.e., 81% positive result). However, although educators showed significant post-workshop gains in their perceived "relevance" of OL and CL statements (79% of **Figure 4b** is green), only 42% of the graduate students found the OL and CL statements "remained very relevant" or were "more relevant" after the FGSC workshops (**Figure 6b**).

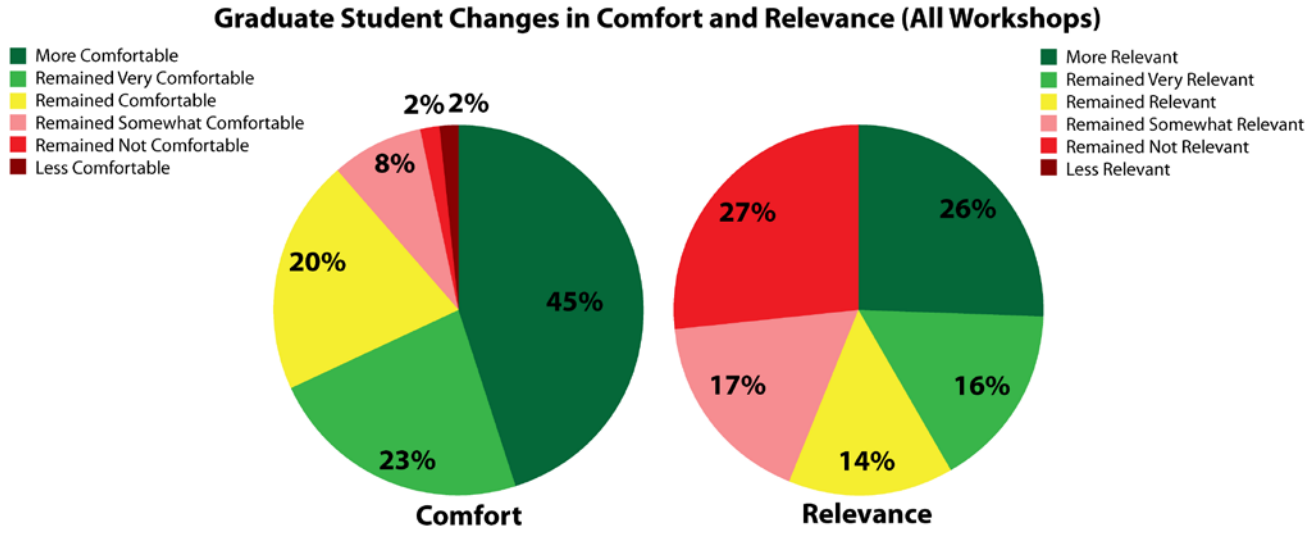

Figure 6. Post-workshop ratings by graduate students on the fundamental concepts covered in the FGSC workshops. The graphic depicts graduate students' change in (a) comfort levels (left, n=343) and (b) perceived relevance of the fundamental concepts (right, n=338) to their work.

Despite the relatively high percentage (27%) of negative responses in terms of relevance of literacy statements (i.e., red area of **Figure 6b**; "remained not relevant"), none of the graduate students indicated the content was "less relevant" in the post-workshop survey. Interestingly, pre- and post-workshop changes in perceived relevance to graduate students had the highest variation of all FGSC metrics: for example, "remained not relevant" responses ranged between an average of 12% at one workshop (n=17) to 48% at another (n=16). One possible explanation might be variation in the degree to which participating scientists modified OL and CL statements to better reflect their own research during the workshops, or incorporated the statements when developing their concept maps. Alternatively, this finding could be interpreted as showing that – even with the small number of institutions that participated in this project – there may be unevenness in how graduate programs train students to balance the focus needed to conduct research with the breadth of knowledge often required to construct relevant linkages within ocean sciences. This finding raised a further question about how students in different graduate programs perceive the value of ocean and climate literacy, but further research is needed to address this inquiry appropriately.

Communication of Science Concepts

As described previously under "Methodology," all FGSC workshop participants (i.e., faculty members and graduate students) – as well as third-party audiences **(Table 2)** – used a simple rubric, an assessment instrument that was originally developed for the SEC workshops, to provide feedback on concept-map based presentations. Presenters were rated on their ability to put ocean sciences research into a "big

picture" context, use of jargon, the organization of the concept map, and the clarity of their "take-home message." On Day Two of the workshop, all graduate students rated individual faculty members' presentations. On Day Three, all third-party audience members rated graduate student team presentations, along with fellow graduate students (i.e., those not the presenting team) who provided peer-level feedback. Thus, during the workshop, graduate students transitioned from being "reviewers" to being themselves "reviewed" in order to help them quickly grasp how concept maps can be used to give effective presentations to a third-party audience. **Figure 7** shows data for the graduate students' final presentations for all workshops (n=547 is the number of responses; each responder rated several presentations), color-coded by type of third-party audience and using a 5-point Likert scale. Overall, the data are quite consistent among audiences: the overall range is only 1.03 points out of a total possible range of 4. In general, the graduate students' presentations were rated highest in terms of "big picture" and lowest in terms of "take-home message." Graduate students' ratings of their peers' concept-map based presentations (n=283; orange data in **Figure 7**) were remarkably consistent with an overall range of only 0.26 out of a total possible range of 4.

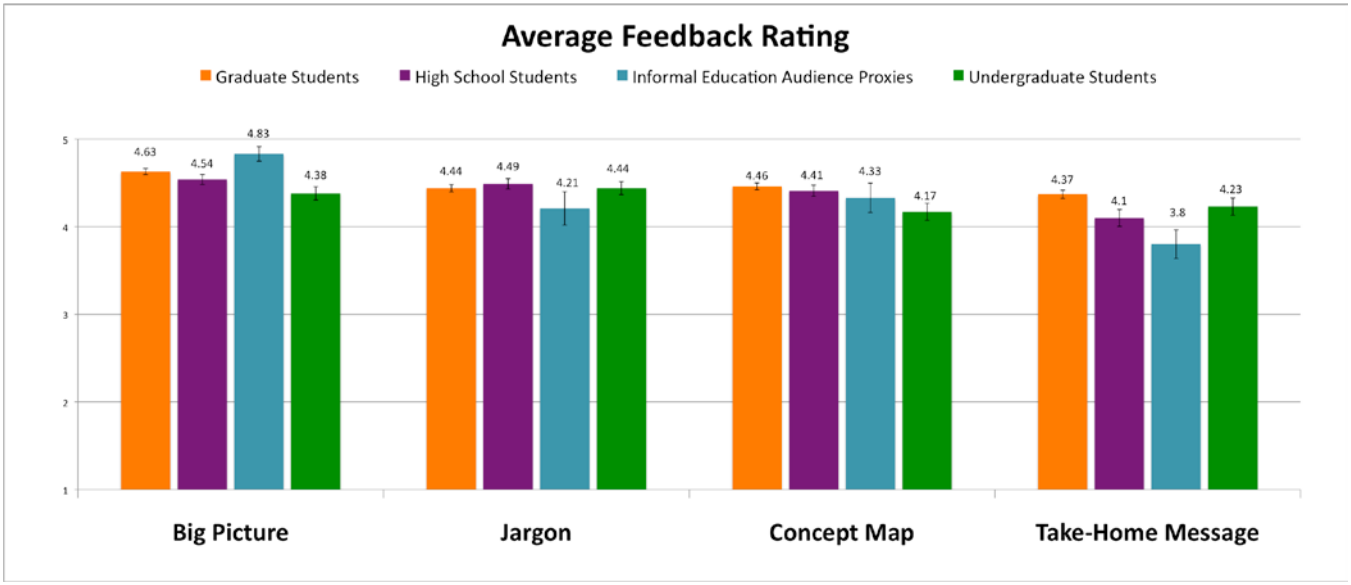

Figure 7. Average feedback ratings on graduate student teams' concept map based presentations on a 5-point Likert scale. Feedback from fellow graduate students is shown in orange and other colors correspond to third-party audiences (i.e., purple for high school students, blue for informal education audience proxies, and green for undergraduate students). Lower values (i.e., 1 or 2) correspond to less effective delivery and higher values (i.e., 4 or 5) correspond to more effective delivery in each presentation category. See Table 2 for more information on participants and the third-party audiences.

Not only did the graduate students look very favorably on their peers' abilities to present using concept maps, but in post-workshop evaluations, they gave the workshops an average rating of 5.9 on a 7-point Likert scale (n=71) for helping them "understand how concept maps are used to present concepts." Likewise when surveyed about the various pedagogical activities offered during the workshops, they rated "giving presentations" as 5.9 on a 7-point Likert scale (n=71). Thus the FGSC workshop model clearly met multiple objectives related to graduate students' use of concept maps as presentation tools. Graduate students were able to successfully communicate science to a variety of audiences*, particularly in terms of placing information into a "big picture" context (Objective 5). They realized that concept maps are viable means of conveying complex material (Objective 2)* and also enjoyed the experience of sharing their end products with non-scientists.

Longer-Term Application of Content or Skills

In late January 2012, a follow-up survey was administered to all graduate students who participated in the workshop series to determine the longer-term impact of the workshops, such as how graduate

students might have applied the content and/or skills. The length of time between the follow-up survey and each workshop ranged between four months and two years (four months for COSEE California; two years for COSEE-OS; **Table 2**). Fifty-one graduate students took the survey (70% of the 73 who participated in FGSC workshops). All were satisfied with assistance received in their workshop from COSEE facilitators. Nearly all (90%; n=51) of the respondents indicated that they would recommend the FGSC workshop to their peers or colleagues, and the same percentage stated that they would like more pedagogical training in their graduate program. Fifty-two percent of the responding graduate students indicated the concept-mapping tools had been useful to them since the workshop and the remainder indicated that they were "not sure," in some cases citing the short time elapsed since the event itself (e.g., COSEE California).

Since the FGSC workshops, the most likely uses of concept mapping in graduate students' broader impacts or educational outreach endeavors were to "better organize thoughts" (63%; n=48) and "provide a bigger picture or context" (54%; n=48). These findings were supported by open-ended responses (see **Box 5** for examples) that indicated concept mapping helped some graduate students both organize and place their research in a larger context. In terms of applying content or skills learned during the FGSC workshops to their scientific research, the most frequent uses of concept mapping were to "organize thinking about an existing research/dissertation topic" (56%; n=48), "develop research/dissertation topic" (44%; n=48), and "explain research to my colleagues and/or peers" (43%; n=48). Nearly all (92%; n=47) of the graduate students indicated that they have already or are planning to add concept mapping to their tools for organizing their research. *Based on these findings and follow-up interviews conducted by a COSEE external evaluator, the FGSC workshops achieved the longer-term objective of having graduate students apply workshop content and/or skills to their own educational outreach, teaching, and research purposes.*

Box 5: Select Quotes from Participating Graduate Students from Follow-up Survey

"[Concept mapping has] helped me in organizing my thoughts for my dissertation to flow in a logical sequence."

"It has made me think more about how the message is conveyed to lay-people."

"[Concept mapping] is a great visual tool to use while presenting concepts to diverse audiences."

"…I included concept maps in my dissertation work, in lectures and presentations, in organizing thoughts instead of taking notes, and… in designing new algorithms e.g. in testing new data analysis tools."

CONCLUSIONS

Based on the recommendations of faculty-level scientists who participated in concept-mapping workshops with educators, staff from four COSEE Centers embarked on designing, testing, and improving a series of workshops for graduate students to introduce concept mapping as a tool to improve science communication. Some adjustments were made to compensate for the loss of pedagogical expertise contributed by educators in the SEC workshop model; however, the correlation in methodology between the SEC and FGSC workshops allowed high-level comparison of the evaluation data from participants in both models. Educators and graduate students gave nearly identical ratings for many components of the workshops, attesting to the overall robustness and the transferability of the concept-mapping workshop model. On the other hand, despite the generally positive outcomes in post-workshop comfort with OL and CL statements for both educators and graduate students, the relevance of this content to ocean sciences research at the faculty and graduate levels is more ambiguous.

After the participants were briefly introduced to other pedagogical approaches, the FGSC workshops focused on training scientists to create interactive concept maps for non-scientists. Concept mapping was employed to help small teams of graduate students and faculty members deconstruct their complex

knowledge into its component parts that were, in turn, graphically reorganized based on the perceived needs of their targeted third-party audience. Evaluation data from graduate students supports the usefulness of concept mapping as an activity to promote collegial discussions with faculty-level scientists. Critical feedback provided to graduate students by their peers and third-party audiences indicates that their final concept-map based presentations were very favorably received, particularly in terms of placing scientific ideas in a "big picture" context.

Results from the follow-up survey data collected from graduate students is encouraging to the authors in terms of how many are applying the skills they developed during FGSC workshops to their own work. This outcome is consistent with the original vision of the faculty-level scientists who recommended that the SEC workshops be revised to include graduate students; that is, assisting these emerging scientists in better understanding and communicating the broader contexts of their research. In addition, feedback from participating faculty members indicates that they recognize concept mapping as a valuable meta-cognitive tool that highlights not just what they know, but how they think. Thus in contrast to the "sage on the stage" role scientists traditionally play in education workshops, this project offered valuable professional development to scientists who, particularly as graduate students, may be expected to teach with little or no training in good education practice.

The authors invite ocean scientists to contact them about implementing a FGSC workshop at their institution.

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